

AN EXAMINATION OF SIGNAL-TO-NOISE ENHANCEMENT AT THE  
EDZELL CDAA (CIRCULA. (U) NAVAL POSTGRADUATE SCHOOL  
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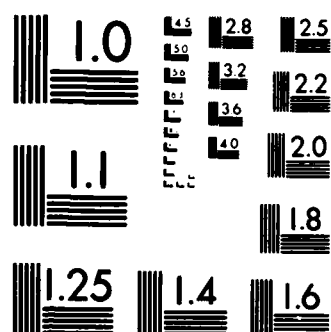
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AN EXAMINATION OF SIGNAL-TO-NOISE ENHANCEMENT  
AT THE EDZELL CDAA

Wilbur R. Vincent, Stephen Jauregui, Jr.,  
John M. O'Dwyer, Michael D. Henry and Larry J. Hume

Project Report for Period Ending 31 August 1984

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Prepared for:  
Commander  
Naval Electronic Systems Command (PDE-107)  
Washington, D.C. 20360

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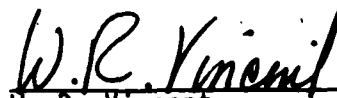
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This report was prepared by:




W. R. Vincent  
Professor of Electrical and  
Computer Engineering

Reviewed by:



H. Rigas, Chairman  
Department of Electrical and  
Computer Engineering



J. N. Dyer  
Dean of Science and  
Engineering

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Extensive measurements were made of signals and noise at several points in the RF distribution system. Any factor that limited signal-to-noise in the RF distribution system was examined.

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Technical Report

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AN EXAMINATION OF  
SIGNAL-TO-NOISE ENHANCEMENT  
AT THE EDZELL CDAA

By: Wilbur R. Vincent  
Stephen Jauregui, Jr.  
John M. O'Dwyer  
Michael D. Henry  
Larry J. Hume

Department of Electrical and Computer Engineering  
Naval Postgraduate School  
Monterey, California 93943

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Washington, D.C. 20360

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## ABSTRACT

A comprehensive survey was made of factors that might yield an increase in signal-to-noise performance of the Edzell EDAA including the improved knowledge and control of internal site and system generated noise, external noise from nearby sources, external noise from distant sources, system generated spurious noise and parasitic oscillations, dynamic range limitations of the RF distribution system, and noise entering or leaving the ground system. The impact of each of the above factors on total site performance was examined in order to better understand the benefits that could be realized from various site improvements.

Extensive measurements were made of signals and noise at several points in the RF distribution system. Any factor that limited signal-to-noise in the RF distribution system was examined.

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## 1. INTRODUCTION

An investigation into factors that limited signal-to-noise in the RF distribution system of HF antennas was conducted at the Edzell, Scotland Circular Disposed Antenna Array (CDAA) during the period of 23 April 1984 to 28 April 1984. The investigation included a general survey of the CDAA to identify the various factors involved in establishing the signal-to-noise at selected outputs of the RF distribution system. The survey included an examination of (1) external RFI propagated into the site from distant sources, (2) nearby external RFI sources that were inductively coupled into the CDAA and the site RF distribution systems, (3) internally generated RFI that was coupled into the RF distribution system by induction or conduction, (4) RFI and noise from intermodulation caused by the insufficient dynamic range of active components in the RF distribution system, (5) noise and signals coupled into site systems by ground connections, and (6) other mechanisms that either limited signal amplitude or produced noise in the RF distribution system. An attempt was made to identify the contribution of each of these categories to signal-to-noise and to limitations in site performance.

The Edzell CDAA investigation was an ongoing part of an overall effort by the U.S. Navy to improve the operational performance of BULLSEYE CDAA sites [1-4]. Prior investigations at other CDAA sites had been completed by the Naval Postgraduate School of Monterey, California (NPS), the Naval Electronics Engineering Activity, Pacific (NEEACTPAC), SRI International, and by other Navy organizations. Measurement techniques, special instrumentation, and results from these prior measurements were of considerable value in conducting the Edzell work.

Some CDAA sites of the BULLSEYE network are now more than 20 years old. Site equipment has changed drastically over this time period due to advances in

technology and as site missions have changed. Many of these changes were made with limited time schedules and with limited resources. In the past two decades, a number of site improvement programs have been implemented with varying degrees of performance improvement. For example, numerous computers have been added to the sites to replace manual operations and to increase signal handling capabilities. These new equipments have been added to the sites alongside old computers and in some cases antique equipment. Of special interest is that the CDAA itself has not been altered or modernized in any significant way during more than 20 years of operation.

The complex collection of old and new equipment in BULLSEYE sites is functioning today with varying degrees of operational reliability and operational performance. There is a general awareness of CDAA performance limitations that are traceable to multiple missions, the complex conglomerate of equipment at each BULLSEYE site, and changes in electrical activity in the general area around each site. This awareness becomes of special concern since new and critical missions are now under consideration for the CDAA sites. The general concern about site performance limitations is, however, not yet supported by hard factual data. For example, only preliminary analyses have been made of site equipment and environmental factors that degrade site performance [2]. These analyses have shown that combinations of factors cause significant performance degradation rather than a single item. Examples are as follows:

- A. Increased man-made noise in the general environment around CDAA sites.
- B. Internal site generated noise from computers, solid state uninterruptible power sources, switching power supplies, digital devices, motor controls, and similar devices.

- C. The use of devices in HF receiving sites that generate HF radio noise.
- D. Poor site grounding techniques that permit intercoupling of power, signaling, and RF grounds.
- E. Intermodulation from devices with inadequate dynamic range to handle signal environment caused by:
  - (1) Increased signal levels directly traceable to a new generation of high-powered transmitters operated by both large and small countries.
  - (2) The increased density of signals in the HF band and the resulting increased signal power fed to multicouplers and active devices.
  - (3) The occasional presence of either in-band or out-of-band parasitic oscillations that saturate active devices and add unwanted input power to the RF distribution system.
  - (4) The pyramiding effects of the additional power from intermodulation components that add to the normal signal power in the RF distribution system causing further saturation and additional intermodulation.

This technical report presents the primary findings of the Edzell CDAA investigation. The results described in the report were obtained by the total team. The primary team members consisted of:

Dr. Stephen Jauregui, Jr., Professor, Naval Postgraduate School  
LT John M. O'Dwyer, Student, Naval Postgraduate School  
LCDR Michael D. Henry, Student, Naval Postgraduate School  
LT Larry J. Hume, Student, Naval Postgraduate School  
LCDR Eugene J. Cummins, Naval Electronic Systems Command, PDE 107  
Mr. Wilbur R. Vincent, Professor, Naval Postgraduate School

## 2. MEASUREMENT SYSTEM

Instrumentation designed for the detailed temporal and spectral analysis of signals and noise at frequencies from 10 Hz to above 1000 MHz was used for the Edzell investigation. The instrumentation consisted of electric- and magnetic-field sensors for the measurement of electromagnetic fields in either the inductive or the distant zones of a signal source and voltage and current probes that could be directly connected to power wires, coaxial cables, or ground wires. Three separate and parallel signal processing instruments were used to analyze the data. A Hewlett-Packard Model 3582A Spectrum Analyzer was provided for spectral analysis of high dynamic range signals that were stable in amplitude and frequency for reasonable time periods. A Nicolet Model UA500A Spectrum Analyzer was provided for the spectral analysis of time varying signals and for the spectral analysis of transients. A Hewlett-Packard Series 140/141 Spectrum Analyzer was provided for wideband spectral analysis and for the spectral and temporal analysis of impulsive signals. The UA500A and the 140/141 analyzers were interfaced to a Develco Model 7200 3-Axis Display to portray time variations of the spectral and temporal features of received signals or received noise. Supplementary equipment was provided to interconnect all instruments into an integrated measurement system.

System parameters for each measurement were listed along with the data. These parameters are often helpful in analyzing the data, and they are provided on a chart located in the appendix. Parameter identification for each measurement system configuration used at Edzell follows.

For measurements made with the Nicolet UA500A Spectrum Analyzer and the Develco 7200B 3-Axis Display, the parameters are:

Line 1 - Local time of measurement, data of measurement

Line 2 - Organization code, measurement site, measurement location

Line 3 - Sensor or probe, line amplifier gain, analyzer input attenuation,  
analyzer output gain

Line 4 - Start frequency, stop frequency, terminate frequency, time axis  
expansion factor

For measurements made with the Hewlett-Packard HP3582A analyzer and  
presented in a two-axis format, the parameters are:

Line 1 - Local time of day, date of measurement

Line 2 - Organization code, measurement site, measurement location

Line 3 - Sensor or probe, line amplifier gain

For measurements made with the Hewlett-Packard 140/141 Spectrum Analyzer  
and the Develco 7200 3-Axis Display, the measurement parameters are:

Line 1 - Local time of day, date of measurement

Line 2 - Organization code, measurement site, measurement location

Line 3 - Sensor or probe, line amplifier gain, analyzer input attenuation,  
analyzer IF gain

Line 4 - Center frequency, frequency scan width, IF bandwidth, scan time

### 3. MEASUREMENTS

#### 3.1 General Approach

Measurements at sites within the United States have usually employed two compatible sets of instrumentation. An instrumentation van has frequently been used for measurements outside the CDAA operations building while portable instrumentation mounted on a cart has been used inside the operations buildings. Moving the instrumentation van overseas for a brief measurement period was not practical, hence the Edzell measurements used only the portable instrumentation.

The portable instrumentation provided a means to monitor signals and noise at any desired point in the RF distribution system. Signals and noise on the CDAA beam or omni-directional outputs could be examined on RF distribution cables used to feed various receivers and systems located in the operations building as well as other locations in the RF distribution system. Sensors and probes borrowed from the instrumentation van were used with portable instrumentation to examine noise and power-line harmonics carried by coaxial cable shields, grounds, and power wiring associated with the RF switch.

For electric-field and magnetic-field measurements that were electrically close to sources, inductive zone considerations were followed. Whenever the distance from a source to a sensor was one-sixth of a wavelength or less, both the electric and the magnetic fields were measured to ensure that a complete understanding was obtained of source electrical properties. Inductive zone measurements required the use of two sensors. A broadband ferrite-cored sensor was used to measure magnetic fields, and a broadband flat-plate sensor was used to measure electric fields. The orientation of sensor axis was also considered where the dominant axis (dominant direction of the field) was always measured.

Current flowing in conductors and grounds was measurement with a Tektronix CT5 Current Probe. Voltage on conductors at frequencies above the 50-Hz and 60-Hz power line fundamental frequencies used at Edzell was measured with a P201D Voltage Probe.

### 3.2 Noise From External Sources

Past measurements at other CDAA sites and at other sites has provided a comprehensive set of temporal and spectral signatures of many types of noise generated by sources external to a CDAA. These signatures provide a means to rapidly identify the presence of external noise sources. The CDAA beams and the DF consoles can often be used to establish the general direction of these



noise sources from the CDAA. This process requires some familiarization with the signatures of typical noise types found in the CDAA RF distribution system and the ability to distinguish external noise from internally generated noise. Fortunately, some external noise sources exhibit distinct spectral and temporal properties that significantly aid in this sorting process. The sorting of external from internal noise sources is simplified and more accurate when the instrumentation van is available to track down and identify the external sources.

During most of the five day measurement period at Edzell, external noise was modest in amplitude in the RF distribution system. Intermittent, erratic, and time varying noise was often observed that adversely affected the reception of low level signals. A very strong noise with characteristics typical of an external source was detected in the RF distribution system on the last night of the measurements. The noise covered the frequency range of 13 to 30 MHz. The upper view of Figure 1 shows the spectral coverage of this noise, and the lower 3-axis view shows slanting lines typical of noise bursts synchronized to a 50-Hz power line. The spectrum analyzer examined signals and noise over the frequency range of 0 to 50 MHz. A more detailed examination of the temporal structure of the noise indicated that groups of noise impulses existed that were synchronized with voltage peaks on the base distribution power lines. These bursts, along with the peaks and nulls of the spectral structure are typical of a nearby gap noise source. Gap noise is produced by minute arcing between two pieces of metal or conducting hardware that are located in a strong electric field. Slightly loose or corroded metal braces, bolts, and insulator supports on poles supporting distribution lines are typical sources of gap noise. The noise peaked in amplitude (with the NCDF console) at 305 degrees.

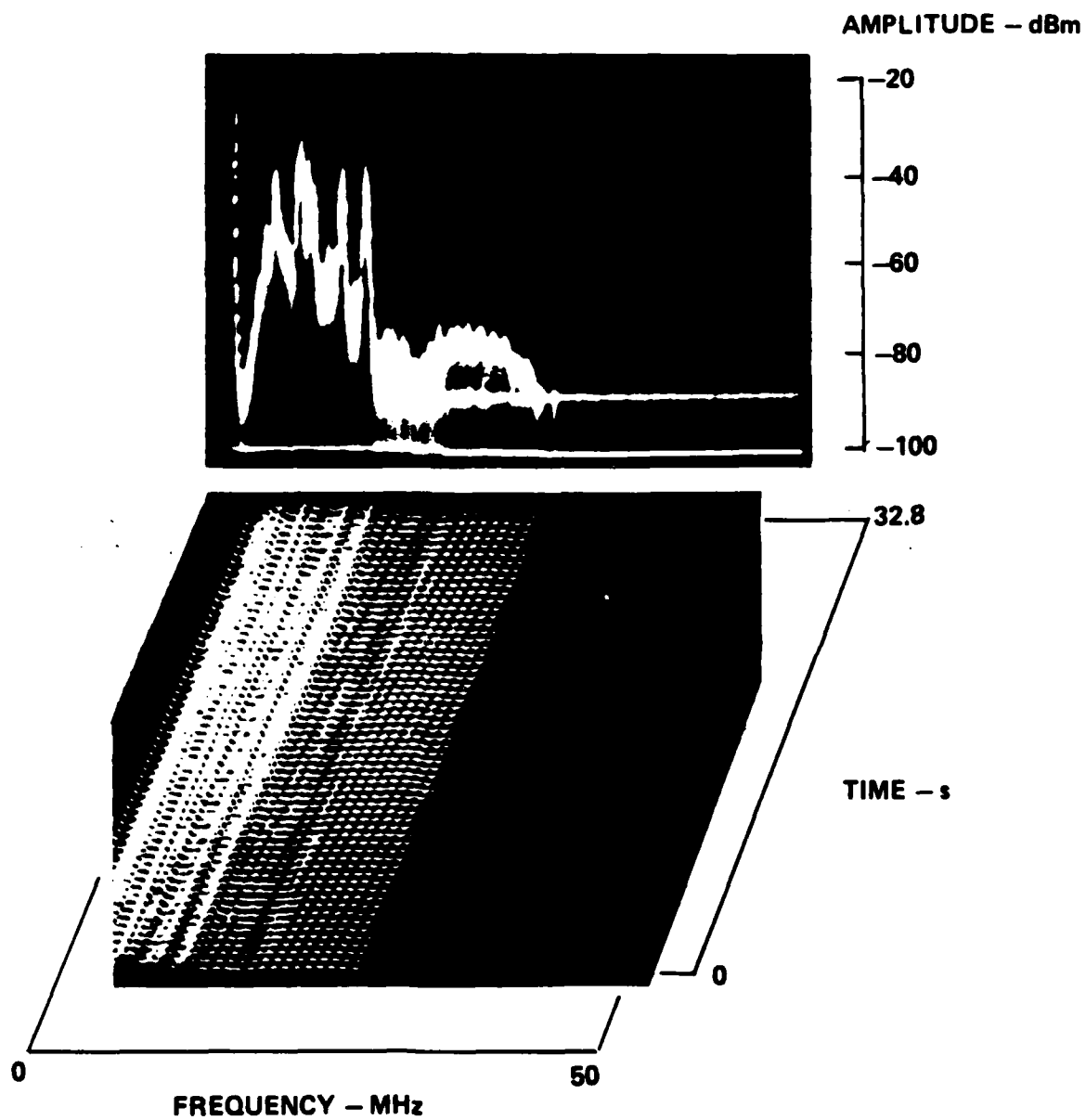
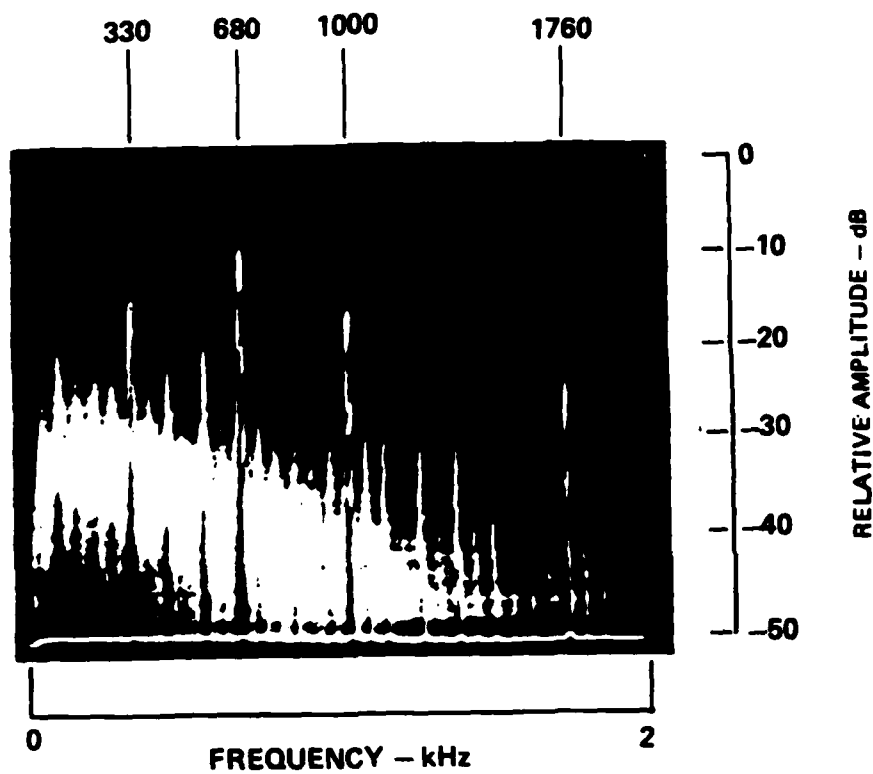


FIGURE 1 NOISE FROM NEARBY POWER LINE

This was towards the administrative area of the base where overhead power lines were used for the distribution of base power.

At the time of the observation of the noise shown in Figure 1 (nighttime), the maximum useful frequency (MUF) had dropped to less than 20 MHz. Most of the noise was above 20 MHz where the direct impact on the reception of signals was low. Only a few signals near the MUF were directly affected by the noise. The total received power of the noise was, however, applied to multicouplers and active devices in the RF distribution system, thus lowering the system dynamic range for handling desired signals.

Figure 2 shows the spectral properties of another form of external noise found at the Edzell CDAA. The figure shows data taken with a portable SSB receiver and recorded on a portable cassette recorder. The receiver was tuned to 3 MHz. The receiver's antenna was placed near an electrical conduit used to protect wires to outside light fixtures. Strong spectral components were found in the receiver's output at 330 Hz, 680 Hz, 1 kHz, and 1.76 kHz. These data indicate that impulses with a very short rise time and at periods related to the 50-Hz power line frequency existed on the conduit. The same interference had been observed on the prior day in the RF distribution system on LBM 5. The lower 3-axis view of Figure 3 shows the temporal structure of the noise (the noise impulses are the slanting lines near the center of the view) found in the RF distribution system. The center amplitude-versus-frequency view shows the amplitude of signals and the noise (about -90 dBm). The upper view shows the temporal and amplitude structure of the noise impulses obtained with the spectrum analyzer frequency span set at 0 kHz. The periods between impulses correspond exactly to those observed on the SSB receiver as shown in Figure 2. The noise amplitude was maximum on a NCDF console bearing of 055 degrees.



**FIGURE 2    SPECTRAL CHARACTERISTICS OF NOISE  
ON CONDUIT**

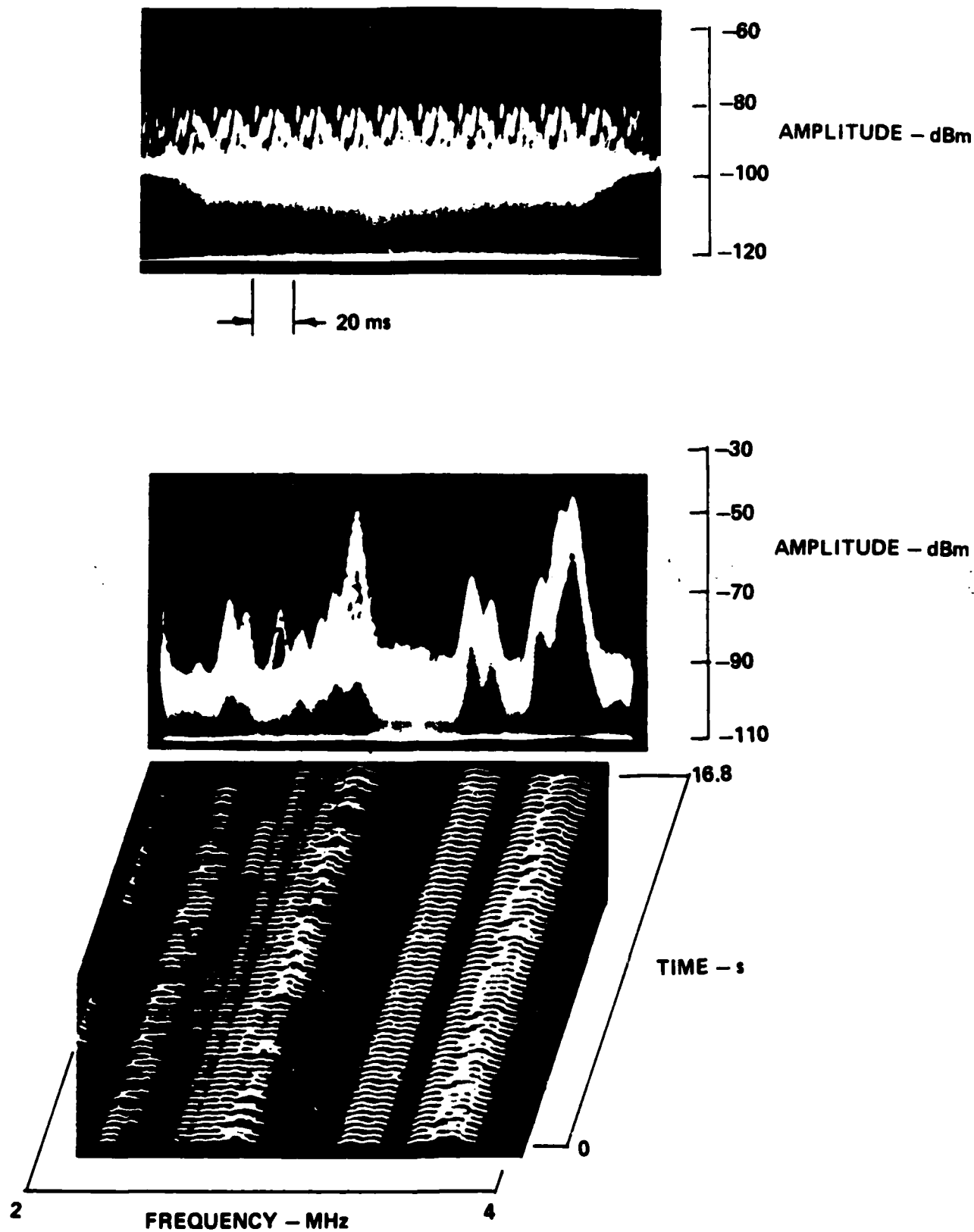


FIGURE 3 TEMPORAL AND SPECTRAL CHARACTERISTICS OF SWITCHING NOISE

High level and random impulses were often observed in the RF distribution system. While the source is believed to be external to the CDAA array, this was not fully verified during the brief measurement period. Figure 4 shows these random impulses as they exceeded a threshold set by the display controls. The impulses were, on the average, about 1 second apart, however, the timing of the impulses was very irregular. The amplitude of the impulses was about -50 dBm.

Figure 5 shows a second example of the random noise impulses taken at a different time than the data in Figure 4. The spectrum analyzer was set to scan from 0 to 5 MHz with an IF bandwidth of 30 kHz. The impulses appear as horizontal dashes in the 3-axis view. Their amplitude was about -60 dBm at 2 MHz, and the amplitude decreased with increasing frequency to a value of -80 dBm at 5 MHz. At frequencies below 2 MHz, high pass filters in the CDAA RF distribution system suppressed the impulse amplitude. The strong signal at 1 MHz was the facility frequency reference which was distributed throughout the facility over the RF distribution system. The amplitude of the random impulses peaked in the early afternoon and faded to low levels after 1500 LT. Attempts to localize the source of this noise with a portable receiver were not successful due to the difficulty of detecting broadband impulses with a narrow band receiver.

### 3.3 Noise from Internal Sources

Out-of-band parasitic oscillations have been found in the RF distribution systems of a number of CDAA's. They were also found in the Edzell CDAA originating from multicouplers associated with LBM 14 and LBM 25. Figure 6 shows an example of the parasitic oscillation for LBM 14 where the strong signal at 81 MHz is the parasitic oscillation. The amplitude of the 81-MHz oscillation was about -25 dBm. The spectral width was about 20 kHz. The

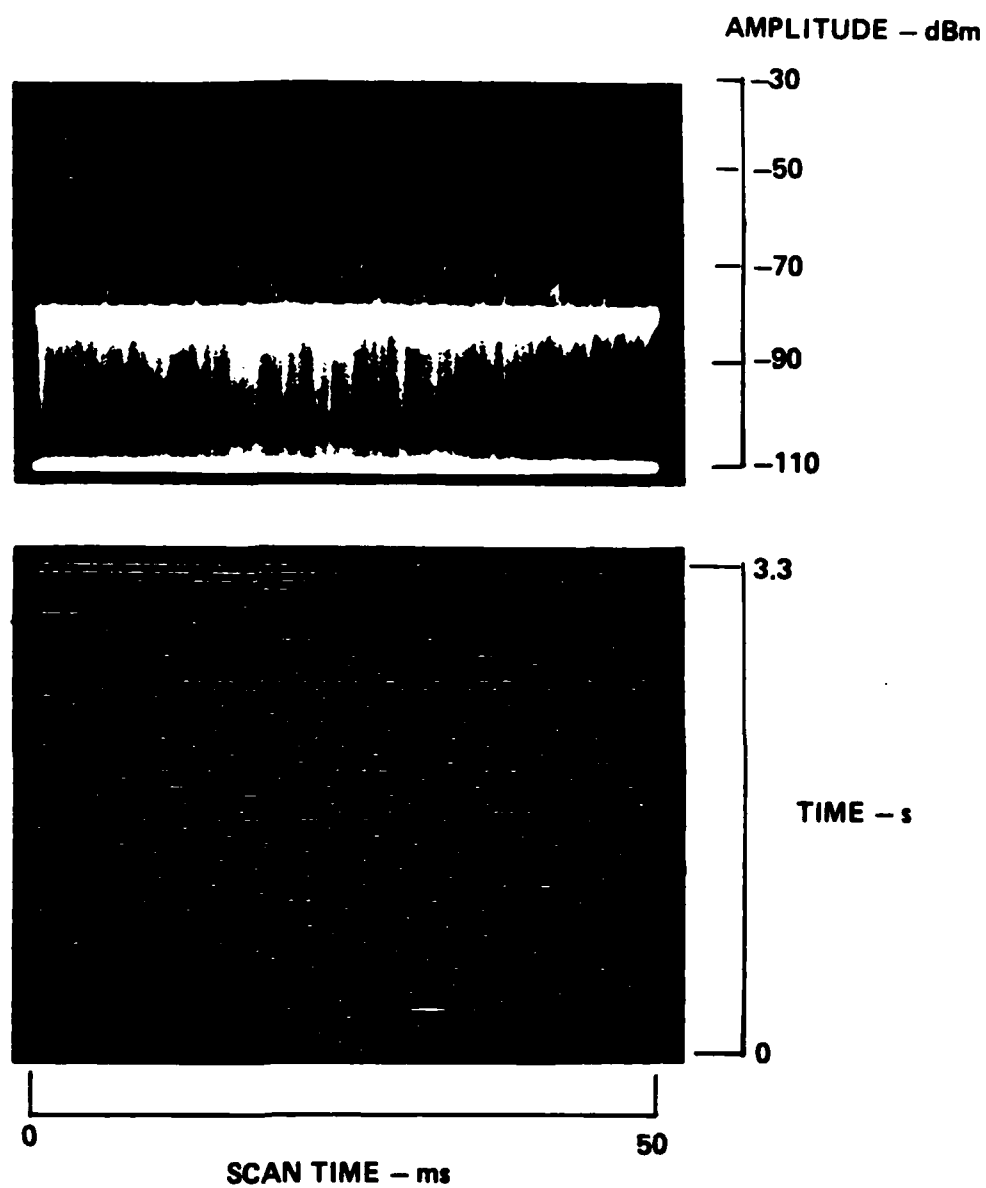


FIGURE 4 HIGH-LEVEL IMPULSIVE NOISE, EXAMPLE A

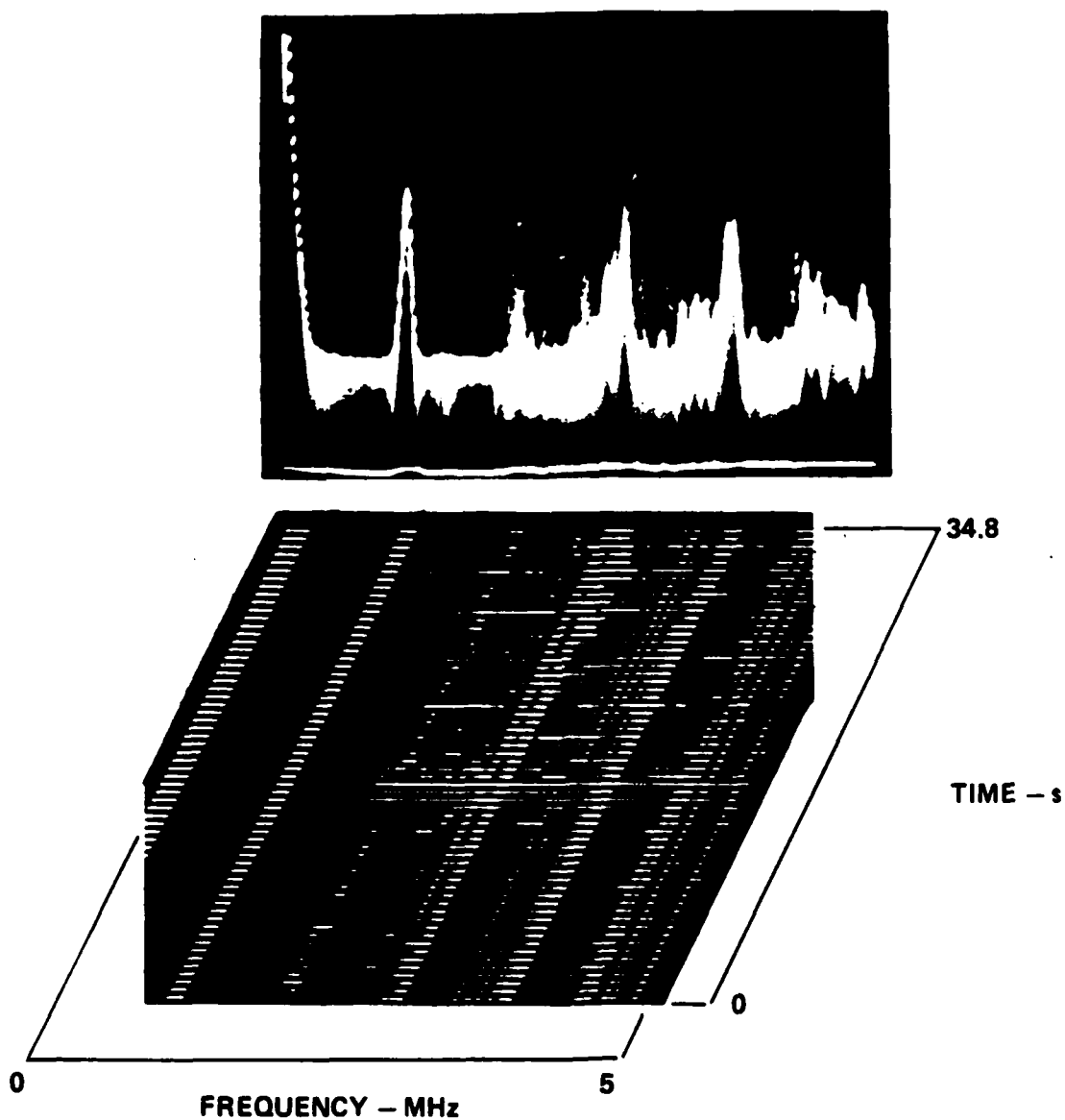


FIGURE 5 HIGH-LEVEL IMPULSIVE NOISE, EXAMPLE B



parasitic signal was amplitude and frequency modulated at 120 Hz by multicoupler power supply voltage ripple.

The out-of-band parasitic oscillations were sufficiently strong to drive the affected multicouplers into saturation. The 81-MHz signal and the nonlinear operation of the multicoupler inverted and translated the entire HF band up into the 50 to 80 MHz VHF frequencies as shown in Figure 6. These translated signals further saturated the multicoupler. The overloaded multicoupler then became more susceptible to intermodulation effects. The source of the multicoupler overloading, the parasitic oscillation and the pyramiding effects of the translated signals, was not directly detectable with HF receivers normally connected to the RF distribution system because of their limited frequency range. These signals were easily detected with an HP 140/141 series Spectrum Analyzer. The parasitic oscillations were quickly eliminated when the faulty Model CU-1280 multicouplers were replaced.

The Edzell site is located about one ionospheric hop away from numerous high power transmitters located in Europe and Asia. While this is the ideal distance for the detection of low level signals, signals from high power transmitters might exceed the operating dynamic range of active components in the RF distribution system. Figure 7 shows signals in the RF distribution system during the evening of 24 May 1984. The maximum signal strength of one signal in the HF band was about +15 dBm. Several signals were received at amplitudes of -8 to -20 dBm. These signals were sufficiently strong to saturate active devices in the RF distribution system for both low band and high band beams 6 through 11. The saturation caused the generation of harmonics and intermodulation products. Figure 7 shows the HF band replicated three times from harmonic generation caused by saturated active devices along with numerous intermodulation products. Intermodulation products also were

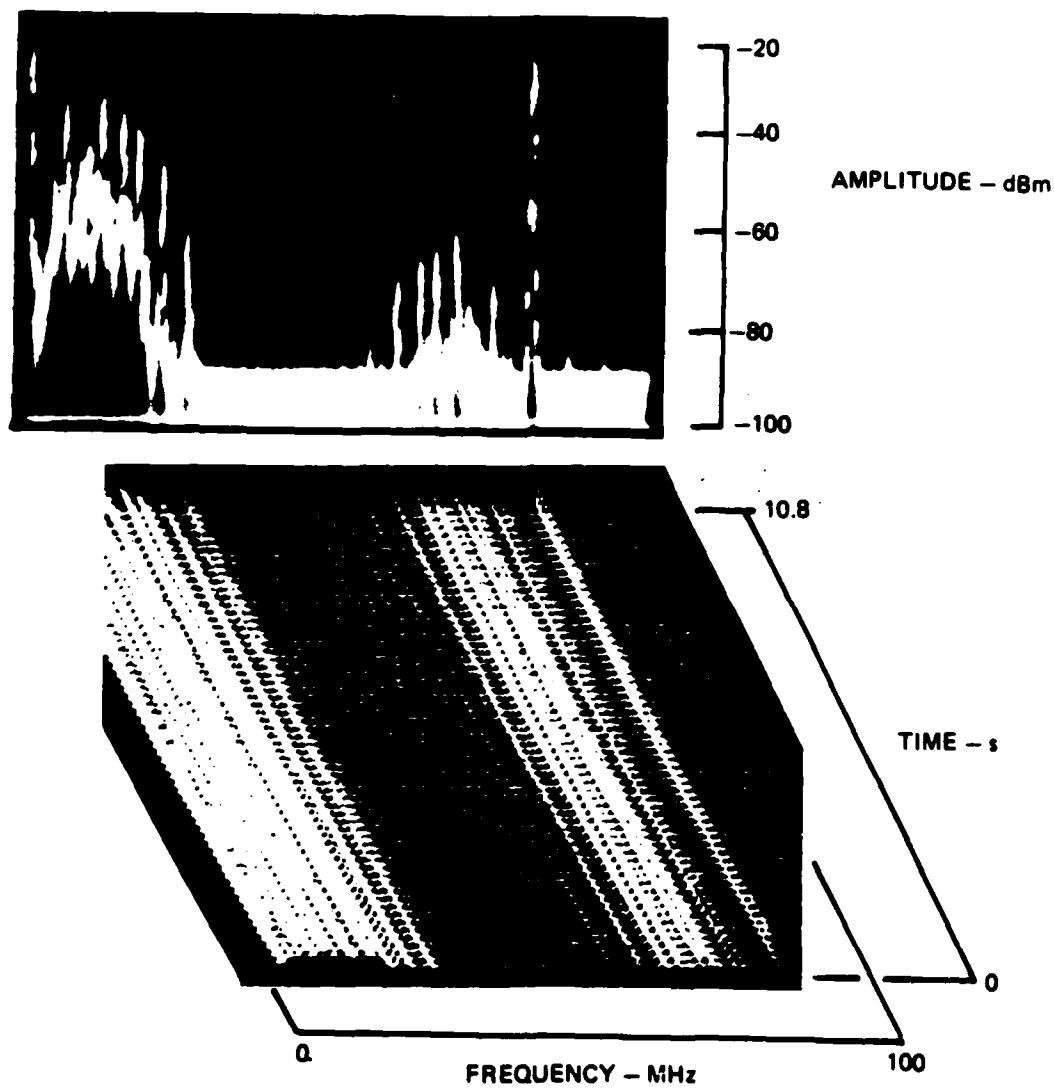


FIGURE 6 PARASITIC OSCILLATION AT 81 MHz

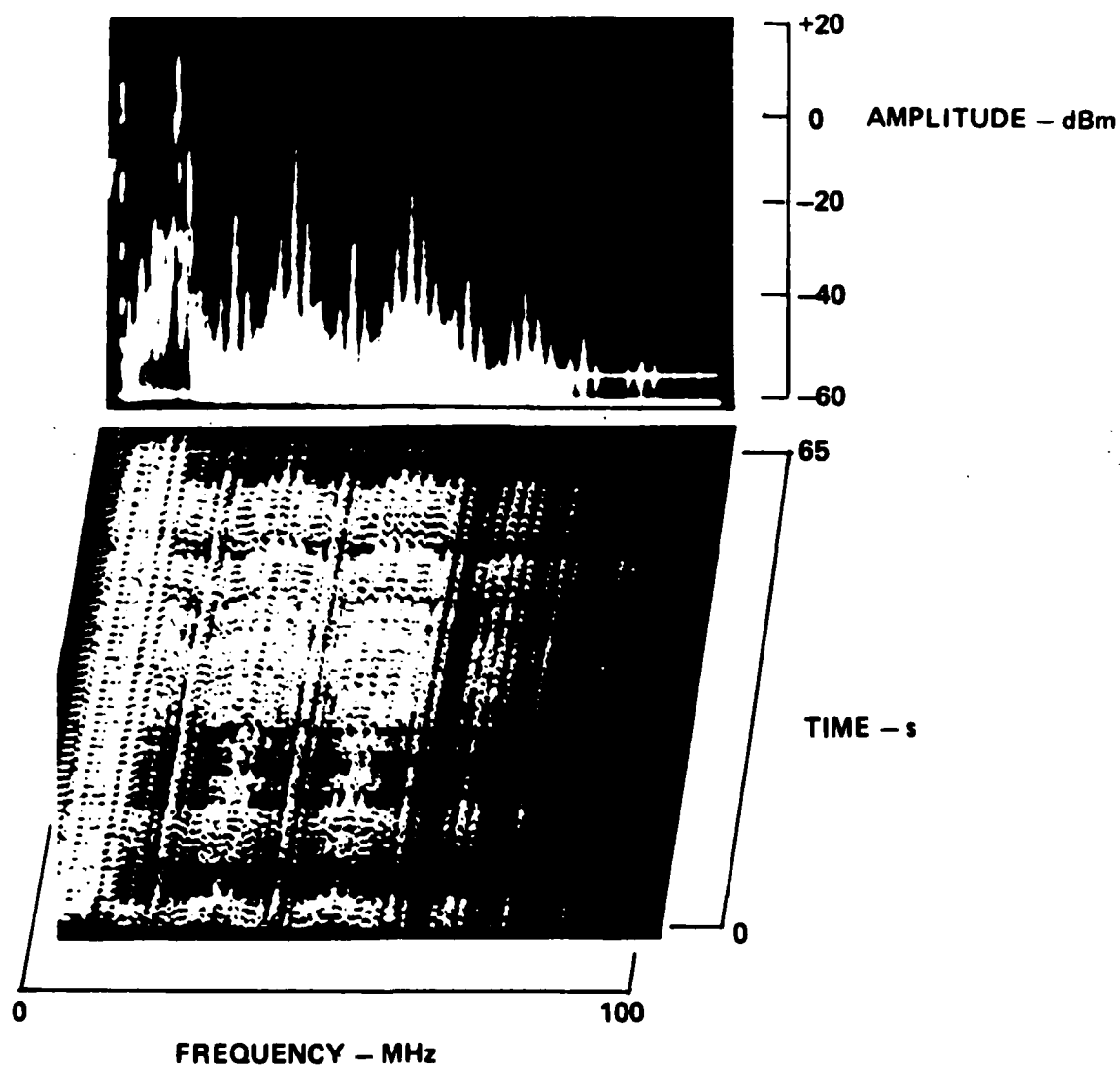


FIGURE 7 REPLICATION OF HF SIGNALS AT VHF

present in the HF band along with the desired signals. This confusing mass of signals, harmonics, and intermodulation made normal manual reception of signals very difficult and machine detection and recognition of signals impossible. During daylight hours ionospheric absorption reduced signal strengths to values below the saturation level for active devices in the RF distribution system and normal daytime signal reception was possible.

Concurrently with the generation of harmonics and intermodulation products shown in Figure 7, low-frequency signals were found in the RF distribution system. Figure 8 shows an example of low-frequency signals over the 0- to 2-MHz range of frequencies. These signals were low-frequency intermodulation products produced by overdriven active elements in the RF distribution system. The intermodulation products slowly increased and decreased in amplitude as HF signals received from distant stations changed in amplitude. These low-frequency signals further contributed to the saturation of active components in the RF distribution system. The entire process of multicoupler saturation rapidly pyramids into an untenable state as the number and amplitude of received signals continue to increase and exceed the operating dynamic range of the RF distribution system.

Figure 9 shows the output of LBM 9 during the day, early evening, and nighttime, about -10 dBm in the evening, and over +5 dBm during the night. The maximum frequency of received signals decreased from the daytime to the nighttime as expected. The data in Figure 9 show that the RF distribution performed as intended during daytime and early evening hours, but strong signals at nighttime caused extreme intermodulation in the RF distribution system as shown in the bottom view of Figure 9. The intermodulation products extended from the maximum frequency of received signals at about 11 MHz to over 90 MHz. Additional intermodulation products were generated within the HF band below 11

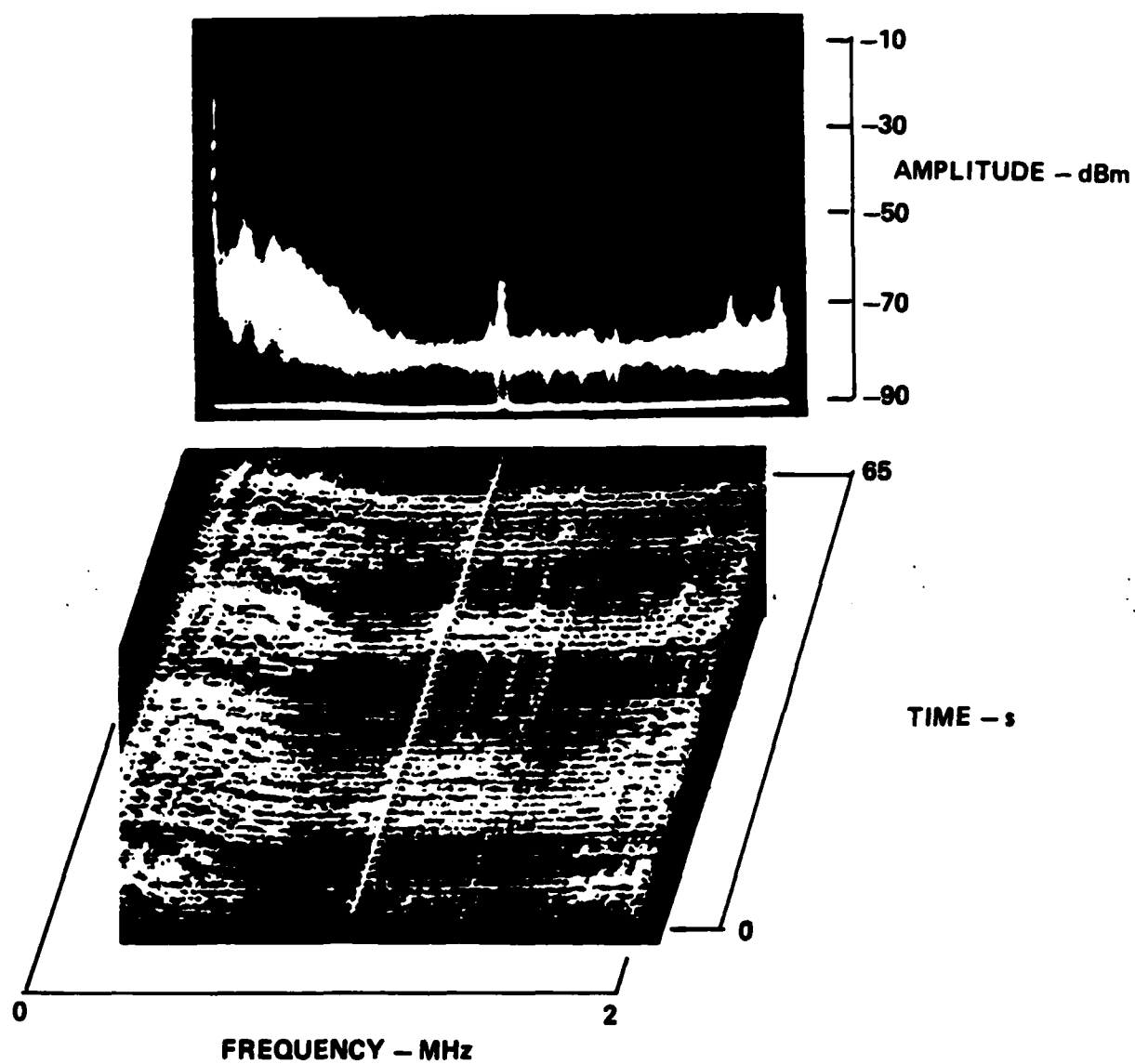
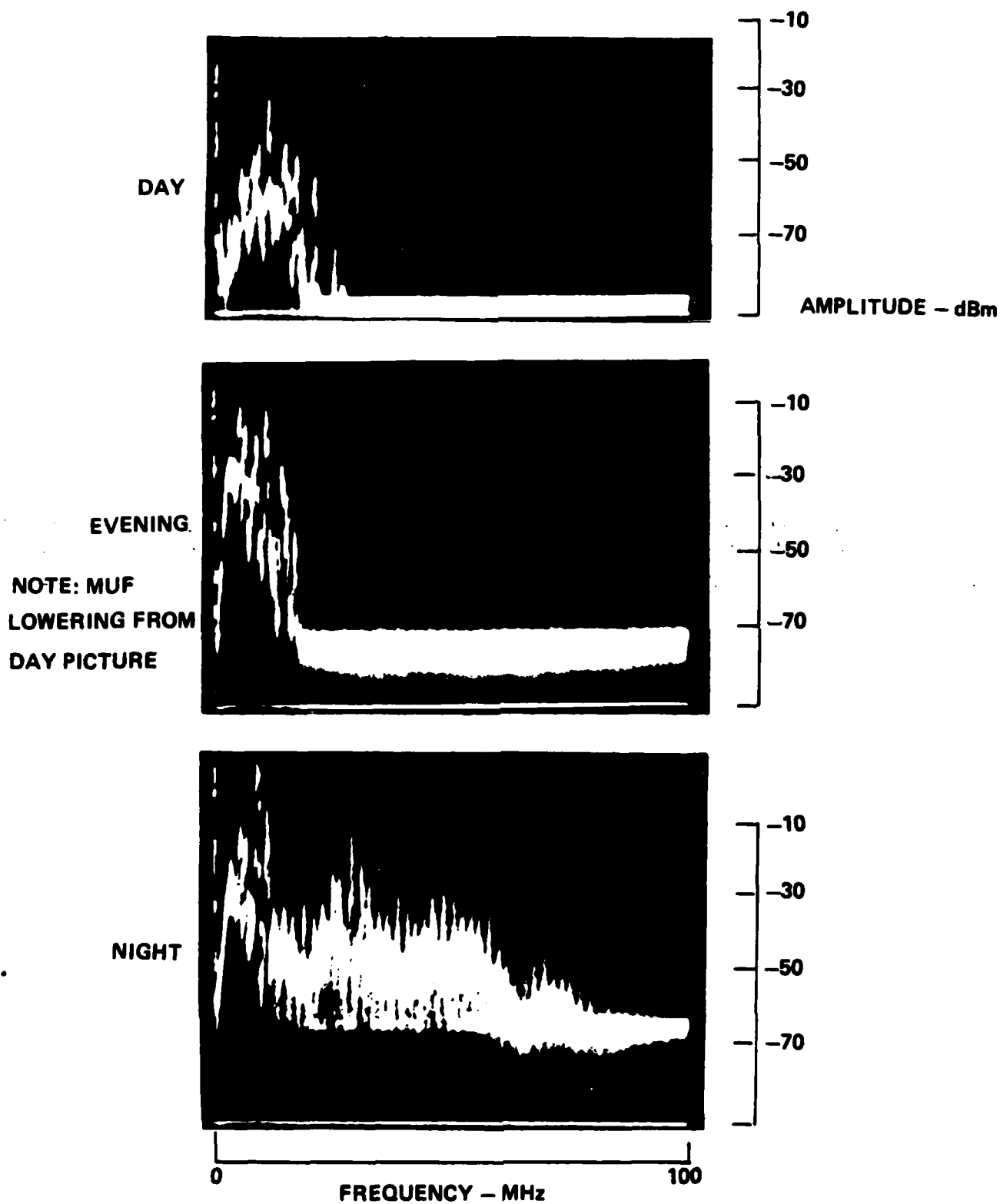


FIGURE 8 LOW-FREQUENCY INTERMODULATION PRODUCTS



**FIGURE 9 LBM 9 PERFORMANCE DURING DAY, EVENING, AND NIGHT**

MHz and at low frequencies. Nighttime performance of the RF distribution system was, at best, poor. The dynamic range of the RF distribution system components clearly was insufficient to handle the effective dynamic range of the nighttime signal environment (more accurately stated as the inability of the RF distribution system to handle the total signal power impressed on the RF distribution system by the CDAA).

Measurement techniques were devised to permit the identification of the source(s) of the nighttime intermodulation, but they were not fully implemented due to a lack of time at the Edzell site. Figure 10 is a simplified block diagram of the signal flow in the RF distribution system. The points labeled 1, 2, 3, and 4 were chosen as measurement locations. Figure 11 shows data obtained at these measurement points during a test run. Data at measurement point 1, the antenna element input, show signals from very low frequencies up through the HF band. These signals included low frequency broadcast signals in the 150- to 250-kHz band, standard broadcast signals in the 530- to 1600-kHz band, and a number of HF signals. The data at measurement location 2 shows the effect of the input filter of the multicouplers where broadcast signals are attenuated and not permitted to enter subsequent portions of the RF distribution system. Locations 2 and 3, before and after the beamformers, gave similar results with only minor differences in amplitude of received signals. A comparison of signals at locations 3 and 4 provide a means to compare the input to the output of the RF switch. Only minor differences were noted at the time of the measurement. These measurements, if made during nighttime conditions when the incoming signal environment exceed the dynamic range of RF distribution system components, would isolate the source(s) of the intermodulation.

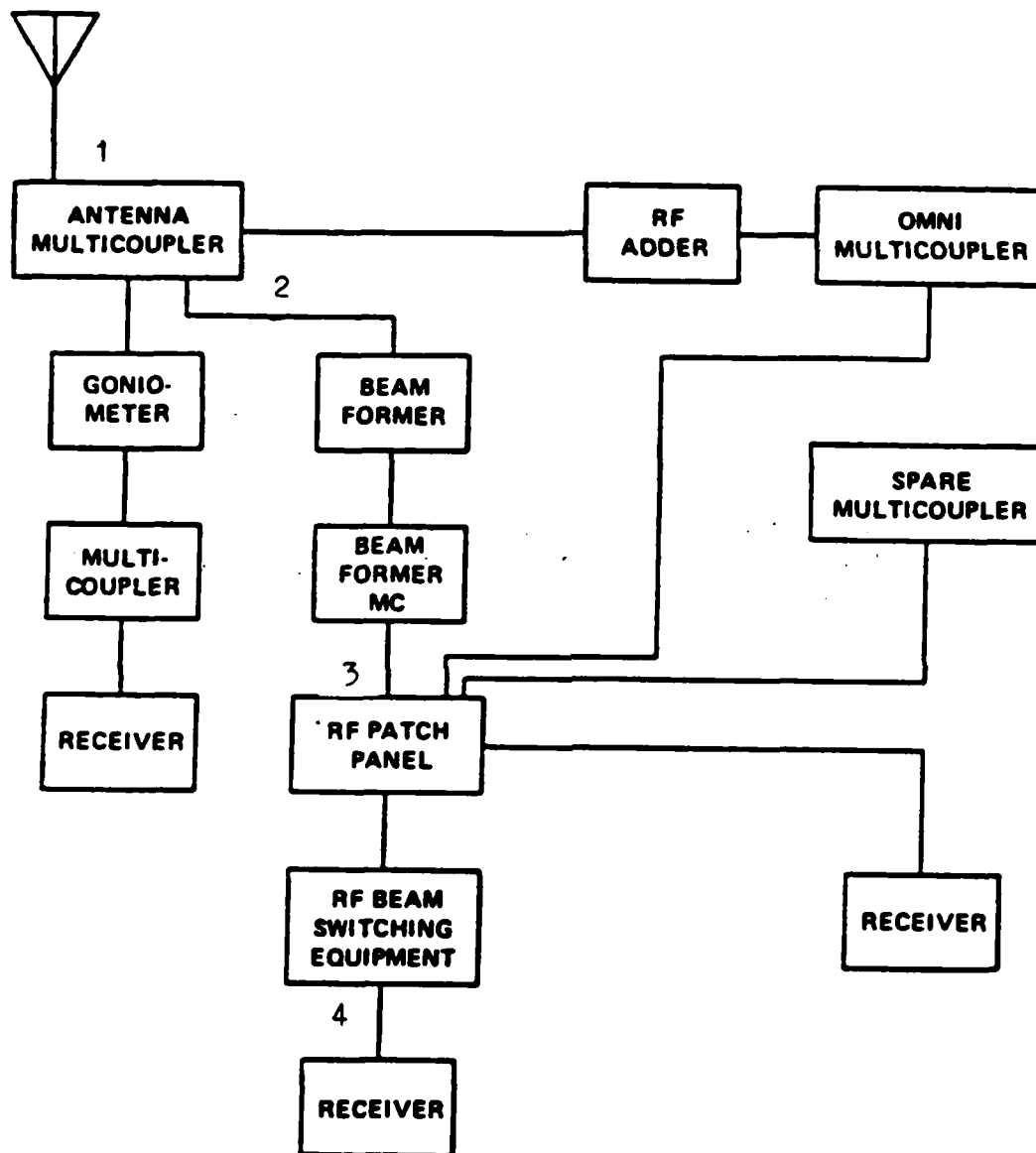


FIGURE 10 BLOCK DIAGRAM OF RF DISTRIBUTION SYSTEM



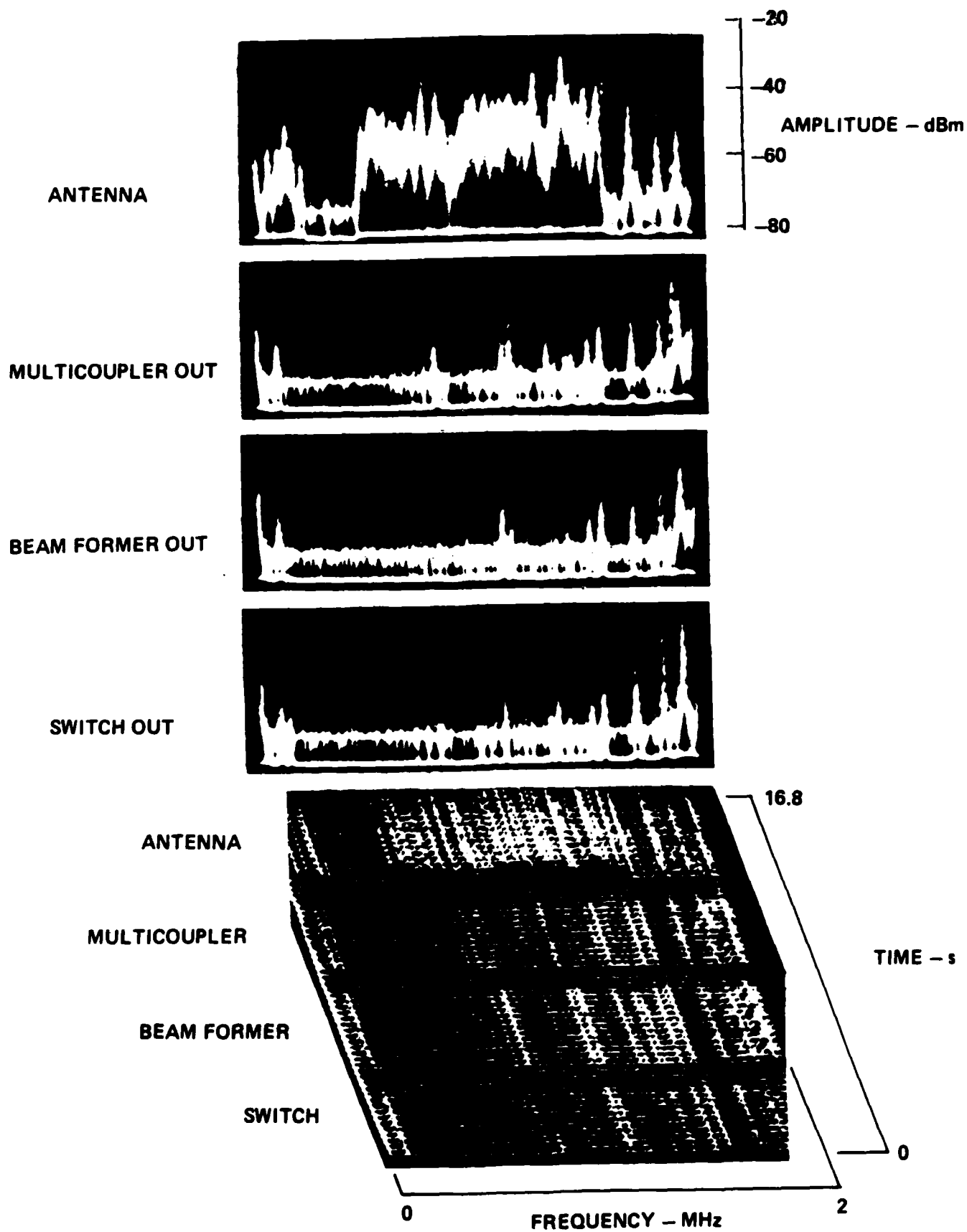


FIGURE 11 COMPARISON OF SIGNALS AT SEVERAL MEASUREMENT LOCATIONS

The bearing cursor of the NCDF (Narrowband Console Direction Finding) was found to be another source of noise in the RF distribution system. While making measurements at the CSP (Control Screener Position) console RF output (measurement position 4 in Figure 10), a strong noise was observed whenever the NCDF bearing cursor was moved by the console operator. The noise was found at frequencies from 0 to about 200 kHz, and the noise was found on all outputs of the CSP console. Figure 12 shows the cursor noise over the frequency band of 0 to 100 kHz. In the top portion of the 3-axis view, the cursor was moved continuously. In the bottom portion of the 3-axis view, the cursor was not moved. The upper view shows the spectral structure of the noise. The noise level increased by more than 70 dB when the cursor was moved. While adverse effects of the noise on HF signals could not be observed during daytime measurements, the cursor noise is still of concern. The noise may be present in active elements of the RF switch where it will intermittently add to the total signal and noise power fed to that active element and increase susceptibility of the switch to intermodulation. The cursor noise is also fed to all receivers and systems served by the RF switch, and several of these systems contain broadband RF sections whose intermodulation susceptibility will be increased by the cursor noise.

### 3.4 Supplementary Measurements

A few measurements were made of current flowing in grounds, green wires, and cable shields. These measurements were made with a Tektronix CT5 current probe and a spectrum analyzer. The spectrum analyzer was used to ascertain the frequency components of the ground currents and to examine various ground leads for the presence of unusual signals.

Figure 13 shows ground currents in a copper strap running underneath a group of multicoupler cabinets. Figure 14 shows the current flowing in a

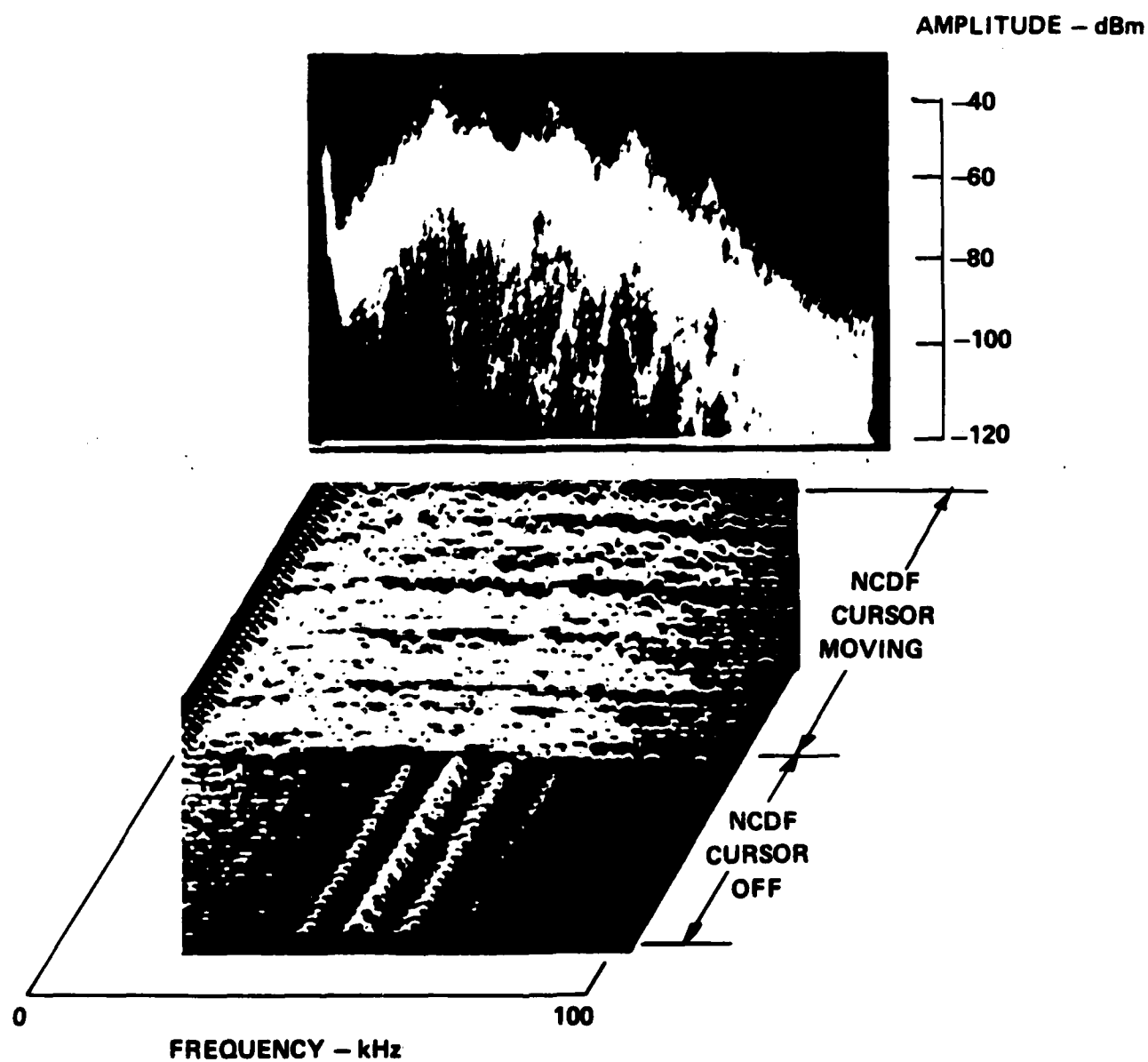


FIGURE 12 CURSOR NOISE

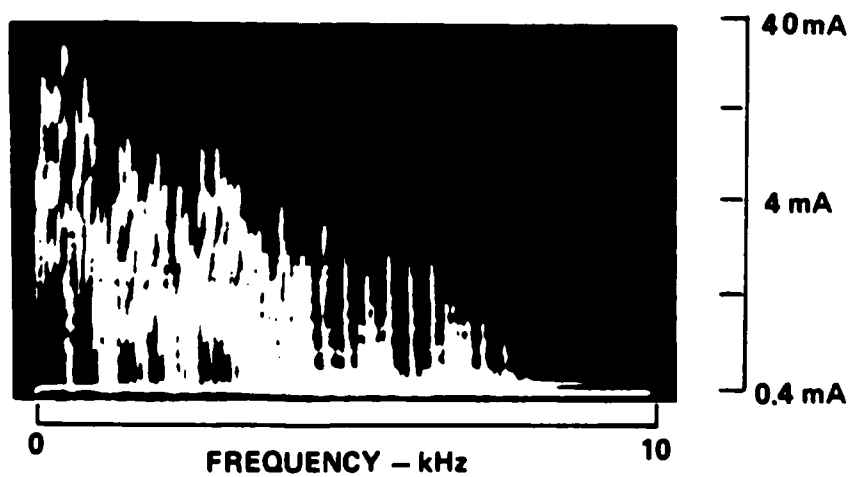
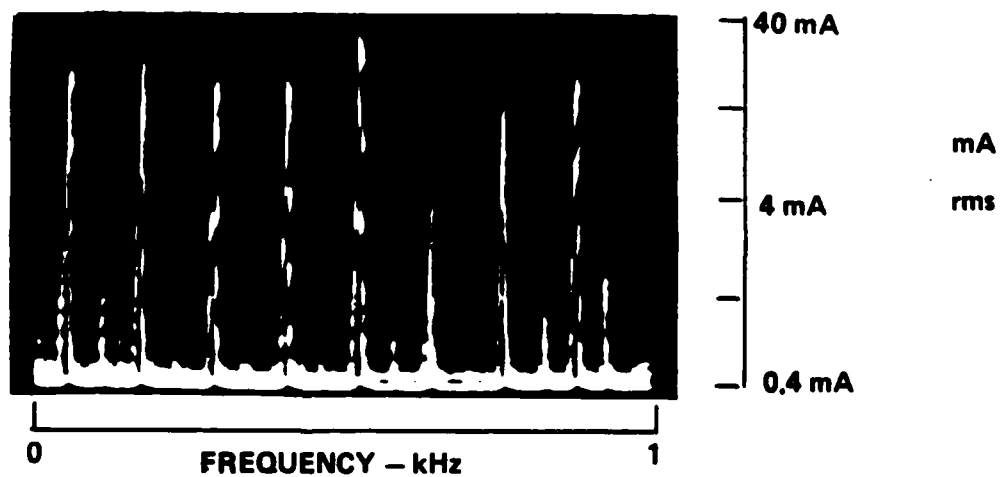
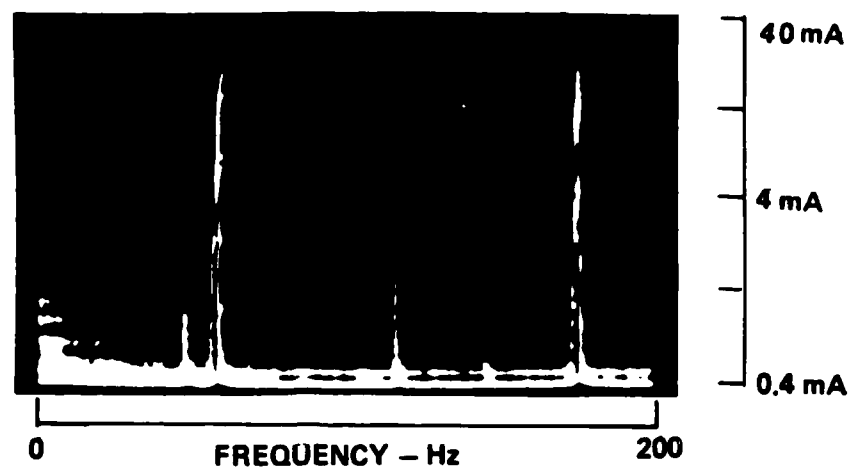


FIGURE 13 GROUND CURRENT FOR MULTICOUPLER CABINET

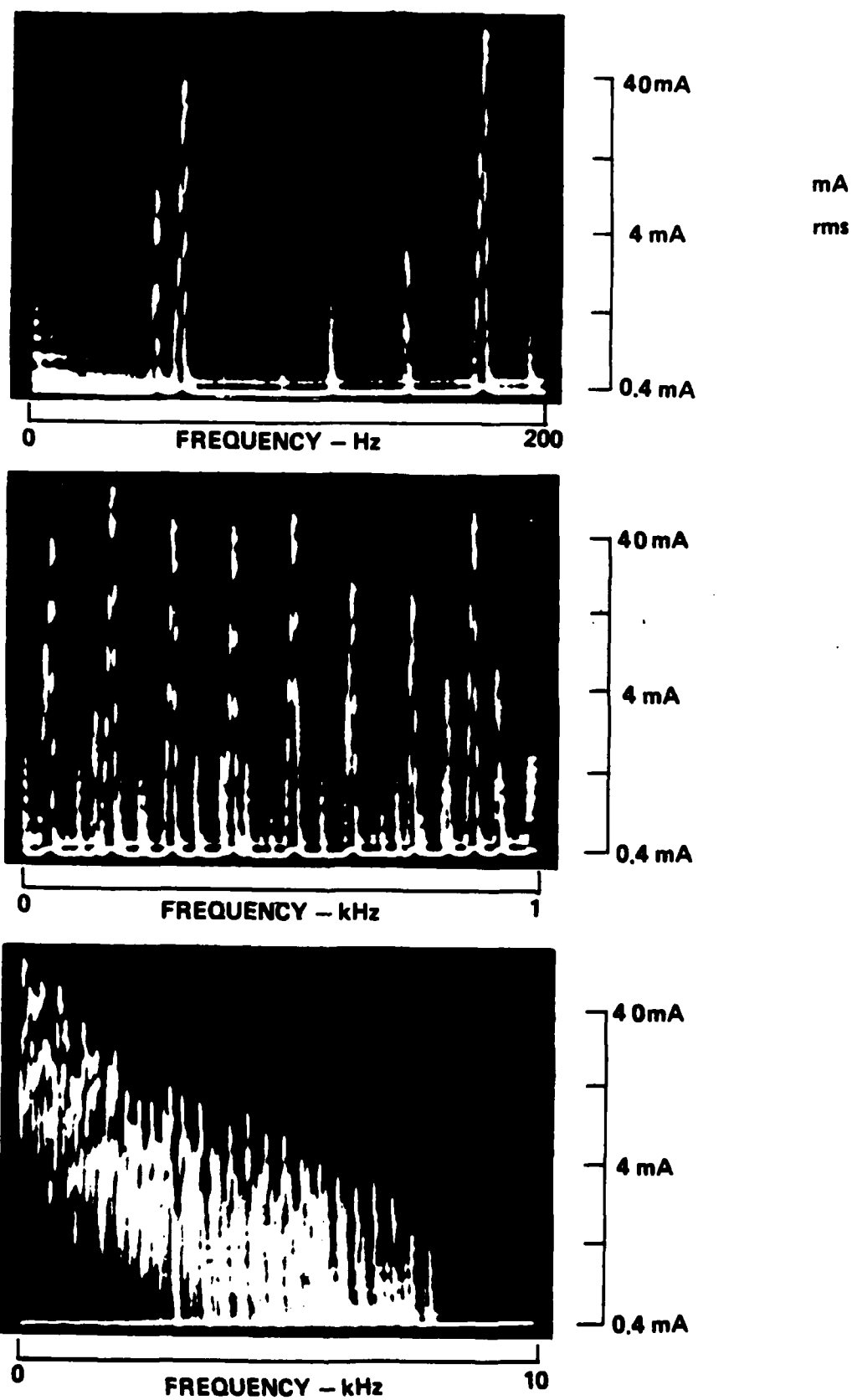


FIGURE 14 GROUND CURRENT FOR SEVERAL MULTICOUPLER CABINETS

ground strap attached to a single multicoupler cabinet. Three views are provided in each figure to show the detailed signal structure at low frequencies and the total effect of all significant harmonics at higher frequencies. A relatively strong 50-Hz current was found in the ground lead to the single cabinet of multicouplers but not in the ground lead for several cabinets of multicouplers. The data also show current at 60-Hz (the fundamental frequency of power for the cabinets) along with harmonics of 60-Hz. Harmonic currents were comparable in amplitude with the fundamental frequency. This would not have been determined from measurements made with a conventional ammeter. The precise path of the 50-Hz current into and out of the multicoupler cabinets was not determined because of the lack of measurement time and the inability to electrically isolate significant sections of multicoupler cabinets at an operational site. Almost certainly the 50-Hz current was associated with multiple ground paths for the multicoupler cabinets and common grounds for power and signal systems.

The low frequency current flowing in a building ground bus was examined in detail. Figure 15 shows current components in the ground bus from 0 to 200 Hz. The 50- and 60-Hz power system currents in the bus are shown as well as time varying subfundamental frequency components. The source of these subfundamental components was not ascertained since this would have required the extensive electrical and physical isolation of portions of the ground system of an operational site.

## 4. DISCUSSION

### 4.1 External Noise Sources

Except for one brief period, the impact of external noise on CDAA operation was moderate in comparison to that observed at many other CDAA sites. Fortunately, no electric power transmission lines were located near the Edzell

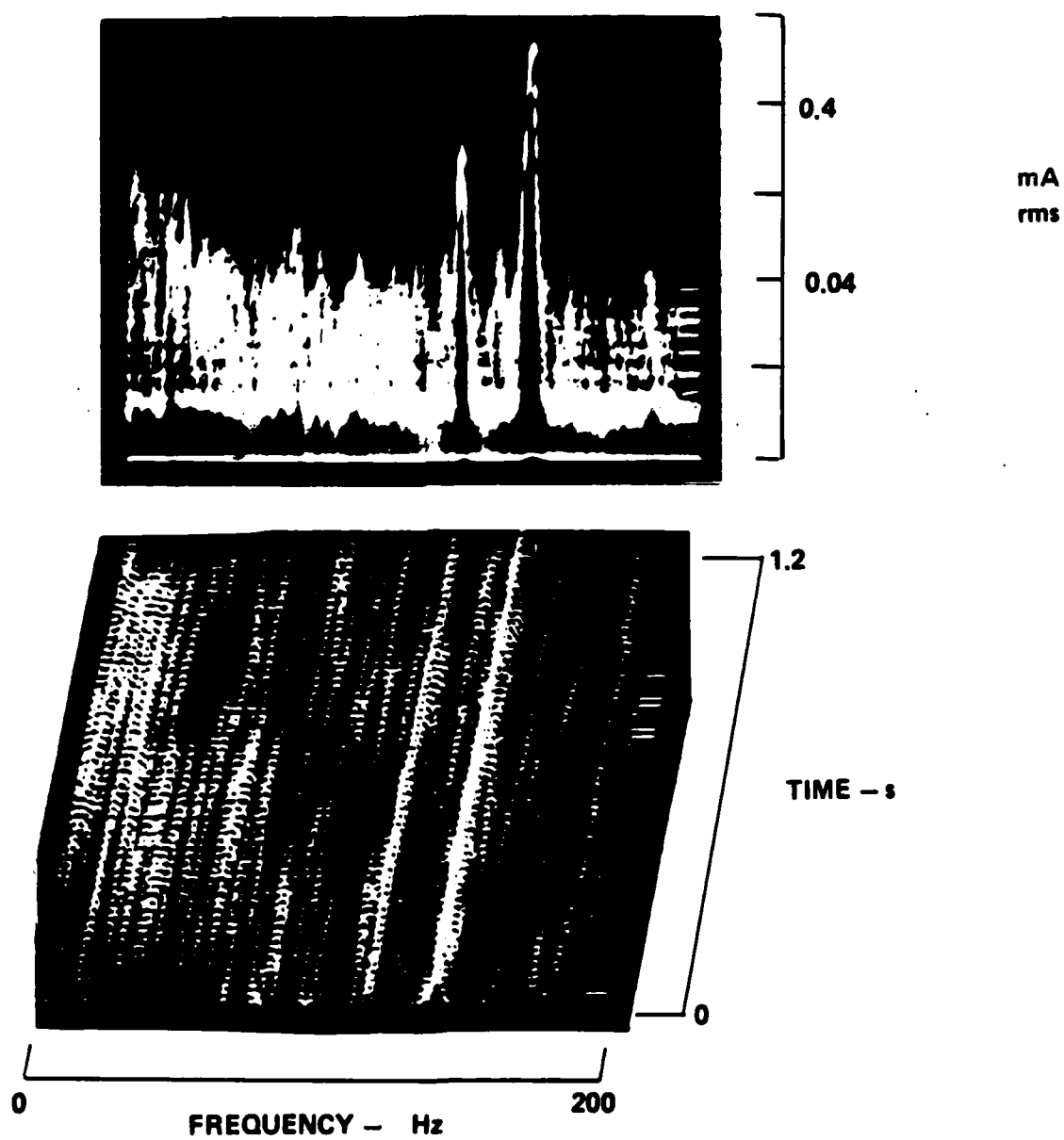


FIGURE 15 LOW-FREQUENCY NOISE ON GROUND WIRE

CDAA, and most nearby overhead distribution lines were located on the base. The nearby distribution lines appeared to be well maintained (this will aid in lowering noise levels but not guarantee low gap noise or low load generated noise emanation from nearby distribution lines). Edzell site managers should exert their best efforts to keep the site isolated from possible future construction of transmission lines within line-of-sight from the topmost portion of the CDAA. Where practical, existing distribution lines on the base should be converted to underground lines to minimize gap noise, and all new construction of distribution lines within line-of-sight of the topmost portion of the CDAA should be placed underground.

The low level impulsive noise frequently observed in the RF distribution system was not serious at this time. This noise appeared to originate from switching devices associated with electrical loads and equipments. The noise was typical of that generated from SCR's used for the control of motors and for the conversion of electric power from one form to another. Several such sources were located near the CDAA whose shielding and grounding were inconsistent with low noise radiation. Impulsive noise was identified in the vicinity of some of this equipment, however, the brief measurement period at Edzell and the lack of suitable measurement equipment did not permit a complete investigation of their potential to affect CDAA operation.

The strong random noise impulses found in the RF distribution system cannot be explained. Suitable equipment for the location of the source of these impulses was not available during the Edzell measurements. The average interval between the impulses (about 1s) was sufficiently low that the impact on the manual reception of signals was minimal. These impulses can significantly affect the performance of some automatic signal detection and recognition systems.



## 4.2 Internal Noise Sources

The parasitic oscillations found in the CU-1280 multicouplers, even though out-of-band, were detrimental to site operation. These parasitic oscillations reduced the dynamic range of the affected multicouplers to unsatisfactory levels and introduced intermodulation products into the RF distribution system from the nonlinear operation of active elements in the multicouplers. Once identified, the parasitics were easily corrected when site personnel replaced the faulty multicouplers. A routine weekly search for in-band and out-of-band parasitic oscillations should be conducted by site personnel to ensure that each new occurrence of parasitics is detected and corrected.

The Edzell site is located one ionospheric hop from numerous high powered HF transmitters, and the resulting signal strengths from these transmitters is unusually high. The total dynamic range of the signal environment at Edzell is much higher than that at most other BULLSEYE sites. During one night when propagation conditions were very good, a maximum signal strength of +15 dBm was found in the RF distribution system. The next evening the maximum signal strength was +5 dBm. The minimum desired system noise level in a 3-kHz bandwidth is about -120 dBm for a unity signal-to-noise ratio. The desired performance of the CDAA for the nighttime signal population observed at Edzell required an RF distribution system dynamic range of 135 dB and 125 dB for these two days. This far exceeded the available dynamic range of active elements in both the multicouplers and the RF switch. The generation of severe intermodulation products in the RF distribution system and the subsequent degradation of performance during nighttime cannot be avoided without some alteration of the CDAA system.

The dynamic range and other related features of the RF distribution system of the CDAA sites was established during the early stages of the construction

of the BULLSEYE network, and this portion of the system has maintained generally consistent operating parameters since that time. The dynamic range of the signal environment has, however, increased considerably over the past several years. New high power HF transmitters have been introduced into the HF broadcast bands (typical power levels have increased from 50 kW to 1000 kW). The numbers and power levels of many other HF stations have increased over the past two decades. The maintenance of a fixed dynamic range of the CDAA RF distribution system of about 80 dB is not consistent with the still increasing dynamic range of the signal environment. The nighttime environment during ionospherically quiet times now vastly exceeds the dynamic range of the RF distribution system. The resulting VLF, LF, HF, and VHF intermodulation products are introduced into all receiving systems that employ the RF distribution system outputs. Some of these systems employ wideband receivers that cover the VLF, LF, and HF bands (for example, the general purpose RACAL receivers that replace the older R390 receivers). VLF, LF, and HF intermodulation products from the RF distribution system add to the signal power that such receivers must handle and reduce their effective dynamic range for normal HF signals.

The intermodulation, harmonic, and overloading problem described above and in more detail in Section 3.3 indicate that normal nighttime performance at the Edzell site can no longer be achieved.

Ionospheric variability will cause considerable variation in the discrepancy between the ever changing day-to-day dynamic range of the signal environment and the fixed dynamic range of the RF distribution system. During periods of poor propagation, the nighttime signal environment will be consistent with current site capabilities. During the summertime months, increased sunlight on the northern hemisphere will increase ionospheric absorption and decrease

signal strengths; resulting in near normal operation. During fall, winter, and spring months, the signal environment will increase to values higher than the RF system dynamic range, and performance degradation can be expected on most nights. The establishment of a precise statistical value for the performance degradation of the Edzell CDAA will require the accumulation of data on day-to-day and seasonal variations in the signal environment or the conduct of a large scale simulation of the site environment accompanied by some validation measurements.

The omni-directional antennas at most CDAA sites are most susceptible to overloading and intermodulation than the beams. Severe intermodulation products were found in the RF distribution system for the omni at Edzell during two prior visits to the CDAA. This was not the case at Edzell during these measurements. The omni-directional antenna outputs of the RF distribution system were generally free from serious intermodulation at all times of the day. This finding suggests that the RF distribution paths for the omni-directional antenna had been modified since the last visit to Edzell, and the omni-directional paths were different from other sites. These differences were not investigated.

## 5. CONCLUSIONS

A number of findings and conclusions were obtained from the investigation of factors that affected signal-to-noise in the RF distribution system at the Edzell CDAA. These are as follows:

- A. Spurious signals and noise were found in the RF distribution system that degraded CDAA performance that originated from sources within the CDAA and from sources outside the CDAA.

- B. External noise, except for one evening, was generally lower than that at most CDAA sites. Severe noise from an unidentified external source was present during one evening that implied the potential for disruptive noise and suggests that a continued watch for disruptive external noise is warranted.
- C. Intermittent and strong noise impulses were found in the RF distribution system during the daytime. The noise would not adversely affect manual systems because of its low occurrence rate, but it could degrade the performance of automatic signal detection systems.
- D. Out-of-band parasitic oscillations in multicouplers were found that seriously degraded RF distribution performance. The faulty multicouplers were replaced by site personnel and normal performance was achieved.
- E. Severe overloading and saturation of the RF distribution system was found during the nighttime when the received signal environment exceeded the dynamic range of active devices in the RF distribution system. The overloading resulted in the massive generation of intermodulation products and harmonics. These products and harmonics further overloaded active devices in the RF distribution system by adding to the signal power. The pyramiding effects of the overloading process were examined.
- F. Because of the serious overloading of the RF distribution system during the nighttime, the effectiveness of the Edzell CDAA during nighttime hours of the fall, winter, and spring months is low.
- G. Very strong noise at low frequencies was found in the RF distribution system originating from operation of the NCDF console cursor. The

precise source mechanism of this noise needs to be identified and a modification to eliminate the noise needs to be implemented.

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## APPENDIX

Following are tables of measurement parameters for each figure used in the report that contain data. The identification of parameters used in the tables is given in Section 3.

### Figure 1

2310, 26 APR 84  
ED, RF SW, HBM-26  
DIRECT, 0, 0, -20  
25 MHz, 50 MHz, 300 kHz, 0.5 s

### Figure 2

1106, 26 APR 84  
ED, CONDUIT, SONY 2002, SONY TC-D5M  
R5, P5, 0, -20, 0  
0, 2, T2, x4

### Figure 3

1002, 25 APR 84  
ED, RF SW, LBM-5  
DIRECT, 0, 0, -30  
3 MHz, 2 MHz, 30 kHz, 200 ms

### Figure 4

1443, 25 APR 84  
ED, RF SW, LBM-1  
DIRECT, 0, 0, -30  
5 MHz, 0, 30 kHz, 5 s

### Figure 5

1313, 24 APR 84  
ED, RF SW, HBO  
DIRECT, 0, 0, -40  
2.5 MHz, 5 MHz, 30 kHz, 500 ms

### Figure 6

1435, 23 APR 84  
ED, SW, LBM-14  
DIRECT, 0, 0, -20  
50 MHz, 100 MHz, 300 kHz, 100 ms

### Figure 7

2300, 24 APR 84  
ED, RF SW, HBM-8  
DIRECT, 0, -30, +20  
50 MHz, 100 MHz, 300 kHz, 1 s

### Figure 8

2321, 24 APR 84  
ED, RF SW, HBM-8  
DIRECT, 0, -10, -10  
1 MHz, 2 MHz, 10 kHz, 1 s

Figure 9  
DAY, EVENING, NIGHT, 24 APR 84  
ED, RF SW, LBM-9  
DIRECT, 0, 0, -10  
50 MHz, 100 MHz, 300 kHz, 200 ms

Figure 11  
2253, 26 APR 84  
ED, RF SW, SEE FIGURE  
DIRECT 0, 0, -10  
1 MHz, 2 MHz, 10 kHz, 100 ms

Figure 12  
0920, 24 APR 84  
ED, RF SW, HBO  
DIRECT, 0, 0, -10  
50 kHz, 100 kHz, 1 kHz, 50 ms

Figure 13  
1100, 26 APR 84  
ED, 10A8 CABINET GND  
CT5, 20/1, 2/1, +40, 0, 0  
0, 0.2/1/10, T0.2/1/10, x3

Figure 14  
1050, 26 APR 84  
ED, 10A5 CABINET GREEN WIRE  
CT5, 20/1, 2/1, +40, 0, 0  
0, 1, T1, x3

Figure 5  
1056, 26 APR 84  
ED, GND BUS  
CT5, 20/1, 2/1, +40, 0, +40  
0, 0.2, T0.08, x4

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